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Sulphur deficiency in acid soils of Tropical Latin America.

Dr. E. Mark Hutton - CIAT

Role of Sulphur in plants.

Most of the plant sulphur is contained in the amino acids cystine cysteine and methionine all of which are vital protein constituents. It follows that a deficiency of sulphur affects growth and protein quality. Sulphur is also involved in the synthesis of the vitamins thiamine, vitamin B_1 and biotin as well as in important metabolic and enzymatic processes necessary to chlorophyl production and growth.

Sulphur is as important to plant growth as phosphorus. Both of these vital elements each constitute about 0.18% of the dry matter of young plants (Andrew, 1977).

Sulphur deficiency in acid tropical soils.

There is very little factual information available on the sulphur status of the surface layers and subsoils of the oxisols and ultisols of countries like Brazil, Colombia, Venezuela, Perú and Bolivia. Increasing evidence indicates that there is a widespread sulphur deficiency in these soils, especially after cultivation. Most of the sulphur in tropical soils is in the surface organic matter which is often at a very low level. Organic matter and its associated sulphur is soon lost in tropical soils by cropping and burning of crop residues. Burning of native grasslands, as in the llanos of Colombia, will gradually deplete any sulphur reserves in the soil.

It is of interest that Cochrane (private communication) has found a close relationship between the levels of sulphur, phosphorus and zinc as well as between the levels of sulphur, phosphorus, copper and calcium in soil samples from different parts of the ICA - CIAT Carimagua Research Station in the Colombian llanos. This relationship could apply to a high proportion of the acid soils of South America as in the Brasilian cerrado and Amazonas. It is quite possible that molybdenum levels are also correlated with the levels of sulphur, phosphorus, zinc and copper. Much more research is needed on the status of the oxisols and ultisols with respect to this important group of mineral nutrients.

Until proved to the contrary, it can be assumed that if an oxisol or ultisol is deficient in phosphorus it is also likely to be deficient in sulphur, zinc, molybdenum and copper as well as calcium. The failure of many legume-based pastures in tropical acid soils appears to be due to ferilization programs based on the assumption that phosphorus is the principal element deficient. Often it is only possible to buy high analyses phosphatic fertilizers like triple superphosphate which correct phosphorus deficiency, but not the equally important sulphur deficiency usually present. Also the essential minor elements mentioned are usually forgotten.

Predicting plant responses to sulphur from soil analyses.

Soil analyses for defining sulphur deficiency have not been very successful. For example, total soil sulphur has a very low correlation with plant response to sulphur in the Australian tropics (Andrew, 1974). However, there was a mean sulphur content of 0.013 per cent in responsive soils and 0.056 per cent in non-responsive soils.

A number of chemical extractants have been used to obtain available soil sulphur and of these, calcium dihydrogen phosphate appears to be the most useful. Using this extractant, Probert and Jones (1977) obtained a good correlation between sulphur extracted from the soil and sulphur response of legumes established in native pastures in different parts of the Australian tropics. They found that a weighted profile mean of 4 ppm of sulphur distinguished the responsive from the non-responsive sites.

Foliar analysis for sulphur.

It is considered that foliar analyses of plants gives a more reliable index of available soil S than soil analyses. The plant material is usually analysed for total S or sulphate - S, with total S being the more commonly used. Care in sampling is needed to ensure significant results. Plant tops should be harvested at the immediate pre-flowering growth stage. With legumes, leaves which have just reached full size give the best results.

Critical concentrations in the plant material below which responses to S applications can be expected have been determined in a number of crop and pasture species. For example, Andrew(1977) found among a number of tropical legumes the following critical S contents in the dry matter - Stylosanthes guianensis 0.13%, S. humilis 0.14%, Macroptilium atropurpureum (Siratro) 0.15%, Centrosema pubescens 0.15%, Desmodium intortum 0.17%. In maize and sorghum a critical S concentration of 0.12% is accepted, while in tobacco the critical value is about 0.25%. It is of interest that Andrew (1977) in field experiments with a number of pasture legumes, found as a result of different soil sulphate treatments, a high correlation between N and S concentrations in the plant tops.

Foliar symptoms of S deficiency are similar to those of N deficiency. For example, in S. humilis a yellowish-green coloration first appears in the youngest leaves and then spreads to the whole plant. Red stem pigmentation is also common. With an advanced S deficiency young leaflets are very narrow and have a red margin.

N:S ratios have also been used for diagnostic purposes (Stewart, 1969). In a variety of crops, for every 15 parts of N in the protein fraction of the plant about 1 part of S is required. Thus N:S ratios greater than 15 or 16:1 often indicate a S deficiency. When S is adequate, about 75% of the total N is in protein. Jones et al (1971) found in S. humilis, that protein N accounted for 70 to 91% of the total N depending on the S status of the plant; S:N ratios increased as S supply was improved.

Pasture and crop varieties more efficient in sulphur use.

It is possible that with proper screening techniques, types more efficient in S use could be selected from varieties or hybrid populations of a species. On the basis of foliar analyses it would appear that *Stylosanthes* species utilize S more efficiently than species like *Centrosema pubescens* and Siratro. However, it is necessary to take into consideration S content, and dry matter and protein yields relative to S inputs.

Among grasses there is some evidence that varieties of *Panicum maximum* tend to exhibit S deficiency sooner than species like *Andropogon gayanus* and *Brachiaria decumbens* when grown on poor acid soils with relatively low fertilizer applications. However, it appears that a S deficiency can be complicated by a Mg deficiency (CIAT, 1977).

Root morphology, and the availability of sulphate in the soil profile, can govern the S response of a species. Thus shallow rooted species can be more responsive than deep rooted ones, because S often accumulates in the lower sub-soil layers.

Sulphur in fertilizers.

In South America there are substantial S resources including volcanic S in Colombia (near Popayán), Ecuador, Perú, Bolivia and Argentina, crude oil S in Venezuela and S containing mineral deposits eg pyrites in Perú, Brazil and Argentina. It seems that with proper organization it should be possible to manufacture sufficient S containing fertilizers in the various countries to overcome the widespread S deficiency in South America.

Single superphosphate containing about 10% of each of P and S and 20% Ca is the best balanced fertilizer for these three nutrients. However, because of greater availability in South America, and lower transportation costs per unit of P, high analysis fertilizers like triple superphosphate have been increasingly used. This has increased the possibility of S deficiency in improved pastures and also cropping. Also it must not be overlooked that phosphate ions can cause the leaching of sulphate ions, and that increased pH's following application of rock phosphate and lime can reduce sulphate retention.

It appears that the native rock phosphates of South America will be used increasingly as a source of P and Ca in the acid soils because of cost and the long term availability of P under the P-fixation conditions induced by low pH, high Al etc. (CIAT, 1978). However, research is also in progress to combine the essential S with minigranulated rock phosphate to provide an ideal source of P, S and Ca for acid tropical soils (Fenster, W.F. and León, L.A., private communication).

Pasture dry matter increases from sulphur fertilization.

Jones et al (1974) summarized all the published work showing moderate to strong S responses in pastures and crops in tropical Australia. Often strong S responses in pot experiments done with surface soil are not correlated with a field response, because of the increase in extractable S at depth in the profile. In most areas where field responses to S have been obtained, the optimum S application varies from 5 to 20 kg/ha. Response to applied S is usually less in freshly cultivated soil than in uncultivated, because of the mobilization of sulphate S following cultivation.

An example of a marked field response to S is given by Miller and Jones (1977). In three field experiments on sites representative of an extensive basaltic area in north Queensland, they found that *Stylosanthes guianensis* responded strongly to S, but not to P or any other element. With the addition of 20 kg S/ha the annual pasture yield was 10,000 kg dry matter/ha, and without S the yield was 4,500 kg dry matter/ha. S content of the pasture was increased by S fertilization from 0.08% to 0.15%. Also a N:S ratio of greater than 17.5 in the *S. guianensis* tops indicated a S deficiency.

Field experimentation is the most efficient method of diagnosing a S deficiency in a soil. It needs to take into account the plant species involved, and also to continue for sufficient time to allow equilibration of the soil reactions. In pasture experiments it has been found that legumes grown with grasses are more likely to get S deficiency than when grown alone. The response of a species to applied S, especially non-legumes, is greater when there is a sufficiency of all other plant nutrients, particularly nitrogen.

Pasture sulphur content and animal production.

If a soil and the pasture grown on it are S deficient, application of S-containing fertilizer raises significantly the dry matter yield and S content of the pasture. It also increases animal production because of greater animal intake and digestibility of the forage.

Rees et al (1974) and Rees and Minson (1978) found with S deficient pangola grass (Digitaria decumbens), that in sheep the size of the increase in voluntary intake and digestibility from S fertilizer was correlated with the S levels in the grass. When the grass S content was increased from 0.09% to 0.15%, voluntary intake was increased by 44%, and when it was increased from 0.103% to 0.157% voluntary intake was increased by 10.5%. It was of interest in these experiments that S-supplementation of the animal also overcame the S deficiency in the diet and markedly increased the voluntary intake of the animal.

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